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A COMPUTER SYSTEM FOR RADIATION THERAPY WITH NEGATIVE PIONS

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ABSTRACT

Since 1974 Cancer Therapy Research has been conducted at the Clinton P. Anderson Meson Physics Facility, Los Alamos Scientific Laboratory, Los Alamos, New Mexico using negative pi-mesons. Through 1977 all treatments will have been static scan treatments, during which a DEC PDP-11/45 computer was used to monitor, record and verify channel and treatment parameters. This computer system has an RSX-11D operating system, and communicates with hardware via CAMAC. Beginning in 1978, dynamic scan treatments will commence and the patient will be moving during the treatment. A PDP-11/Ø3 microprocessor will be used to move the patient in three dimensions and one rotation, and to control beam-modification devices such as slit jaws and a variable-thickness range shifter. Simultaneously the treatment will be monitored and verified by the PDP-11/45 computer.

Key words: bending magnets, bolus, CAMAC, dynamic scan, negative pi-mesons, pion star, quadrupole magnets, range shifter, RSX-11D operating system, slit jaws, static scan, target, treatment planning, wedge

INTRODUCTION

The Clinton P. Anderson Meson Physics Facility (LAMPF) is one of five facilities which is developing a negative pion radiotherapy program. LAMPF is located at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico. In using pions it is possible to improve the therapeutic ratio between malignant tumors and normal tissue mainly due to the highly localized dose distributions that can be obtained. When pions uniformly stop in a one-liter volume, each pion deposits approximately 35 MeV (low LET) due to dE/dx plus another 40 MeV (some high LET) from the star that is formed when the pion is captured and decays. When LAMPF reaches its design goal of one mA of proton beam current, we should be able to give doses larger than 100 rads/min. in a one-liter volume.

Pions are produced when protons from the half-mile-long linear accelerator strike an 8 cm long graphite target. The design goal is to produce 1.0 E+11 pions/min. The pions are collected and transported to the patient by the quadrupoles (lenses) and bending magnets of the Biomedical Channel. One of the functions of our computer system is to control and monitor the channel magnets, slits, and wedge.

CURRENT STATUS

The Biomedical Control Computer is a PDP-11/45, and the operating system is RSX-11D, which is a real-time multi-tasking operating system. This system allows a wide variety of tasks to run simultaneously. One of its features is time slicing, which gives us the capability of having all tasks below a certain priority level rotate on the active task list. Tasks rarely have to wait more than a few seconds before they have access to the CPU.

Most of the software that communicates with channel hardware was written to be interrupt-driven rather than continuously polling the hardware to see if it needs servicing. For example, in setting a magnet the appropriate countdown register is loaded with a number and the task suspends. Then the countdown register, in conjunction with associated hardware, changes the magnet by an amount proportional to the number that was loaded into the register. When the countdown register reaches zero, i.e., when the magnet reaches it set point, the task is resumed and minor adjustments can be made to the magnet set point. By using the interrupt-driven technique rather than the polling technique, the demand on the CPU and the Unibus is greatly reduced.

In communicating with hardware the PDP-11/45 addresses (via the Unibus) a Microprogrammable Branch Driver (MBD), which in turn controls (via the branch highway and a CAMAC crate controller) a CAMAC module, e.g., a countdown register, which in turn sends appropriate signals to (or receives them from) a specific piece of hardware, such as a magnet controller.

To treat a tumor of a certain shape and size the radiation therapist requires the pion stopping distribution to have roughly the same shape and slightly larger size so that it can be collimated. In order to deliver such a beam the operator sets the channel to a particular "tune", i.e., each magnet is set to a specific current, the appropriate wedge is inserted, the slit jaws are positioned correctly, and the target is inserted into the proton beam. In actual practice, to set up a tune (for example, #23), the operator presses a button labeled "Tune 23" and all channel elements except the target are set automatically. This can be accomplished while the medical team positions the next patient.

Controlling the dose distribution in depth is somewhat more difficult. One technique is to control the momentum (i.e., stopping) distribution of the pion beam by inserting the appropriately shaped wedge at the intermediate focus. The most optimally designed wedge gives the narrowest stopping distribution in depth, $\approx$ 3 cm FWHM by selectively degrading the higher momentum particles. Larger stopping regions can be obtained with less optimal wedges (or no wedge), but it is very difficult to control the shape of the stopping distribution. Our preferred technique employs the most optimal wedge and a variable-thickness degrader or range shifter. The thickness of the degrader can be controlled by the computer, hence the shape of the depth distribution can be accurately determined by the computer.

In preparing for a treatment considerable treatment-planning work is done on the computer. It is in this stage of the work that the shape of the collimator aperture, the shape of the density compensating bolus, and the treatment time are determined.

Through 1977 only "static" treatments will have been given, that is, treatments in which the patient does not move. For each treatment the therapist sets four numbers on thumbwheels, any one of which will terminate the treatment when a corresponding counter reaches the thumbwheel setting. The thumbwheels/counters correspond to pion-flux monitor no. 1 (ion chamber no. 1), pion-flux monitor no. 2 (ion chamber no. 2), proton beam on target monitor, and treatment time. These four independent systems are calibrated at the start of each treatment day, and are set at 1.00, 1.05, 1.10, and 1.15 times the desired dose respectively.

During a treatment the computer monitors, records and verifies treatment and channel parameters. Since these are non-essential functions, the treatment can be given without the computer. However, the use of the computer has been found to be very beneficial, as it has often detected errors in thumbwheel settings, and warned of slight drifts in magnets, and other potentially hazardous conditions. The computer, in addition, greatly reduces the set up time prior to a treatment, and outputs a detailed log upon termination of the treatment.

FUTURE PLANS

Early in 1978 "Dynamic Scan" treatments will begin. A Phillips "couch" system has been installed in the treatment room, and a second one in the simulator room. Each couch can be moved with five degrees of freedom, i.e., z = vertical translation (along beam line), x = longitudinal and y = lateral translations, θ = rotation about the vertical beam line, and ϕ = rotation about a vertical axis 40 cm from the beam line. At present the ϕ rotation can be accomplished manually only. A PDP-11/03 microprocessor is interfaced to the two couches. All five degrees of freedom are monitored by the microprocessor and the PDP-11/45 computer. To determine the position (orientation) of the couch, each computer reads a 12-bit Gray-code optical shaft encoder for each of the five axes. As a backup each computer also reads a pot voltage for each of the five-position coordinates, and these are compared to the encoder readings. Instead of using CAMAC, the microprocessor reads the encoders with a parallel interface through an 8 to 2 multiplexer and the pot voltages with an analog-to-digital converter.

The microprocessor can move the treatment room couch in x,y,x and θ by means of digital-to-analog converters (DAC's) connected to motor drivers. The range shifter (RS) will also be driven by a DAC in the microprocessor and its position will be determined by the same four techniques that the x,y,z,θ, and ϕ values are determined.

A new addition to the Biomed Channel will be two jaws (J1 and J2) just below the range shifter. Each of these jaws can be positioned by the microprocessor and their positions determined in four ways in a manner similar to the range shifter.

A typical dynamic scan treatment may be carried out as follows: 1) While the medical team is positioning the patient on the treatment couch, the operator presses a button to set up a tune which produces our smallest possible pion-stopping distribution, symmetric in x and y, i.e., circular in shape. 2) Treatment files are then transmitted from the PDP-11/45 to the PDP-11/Ø3 via parallel interfaces. 3) The microprocessor positions the patient to the first point (x, y, z, and θ). Minor corrections to this position may be applied at this time. 4) The treatment room is cleared of all personnel except the patient, the target is inserted and the treatment commences. 5) The treatment volume is scanned vertically by the range shifter at 60 tiny steps per second. Simultaneously one jaw (or possibly both jaws) will be moved in synchronism with the range shifter to define an edge of the treatment volume. Obviously, this edge can vary with depth. The jaw will be moved only if the x and y coordinates of the beam spot are near a tumor edge. 6) The patient is translated to a new x, y, and z. If x and y are near a tumor edge, the patient is rotated so the edge is parallel to the face of a jaw. Step #5 is repeated. 7) Step #6 is repeated until the entire volume of the tumor is treated. 8) The jaws close quickly, the target is withdrawn, the patient is removed, the next patient is brought in and a new treatment is begun.

Needless to say, dynamic scan treatments will not be given without the PDP-11/Ø3 microprocessor, and, hopefully, not without the PDP-11/45 computer for back-up verification and recording.